PROJECT ID: EEMS052

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

Resiliency Analysis for Automated Mobility Systems

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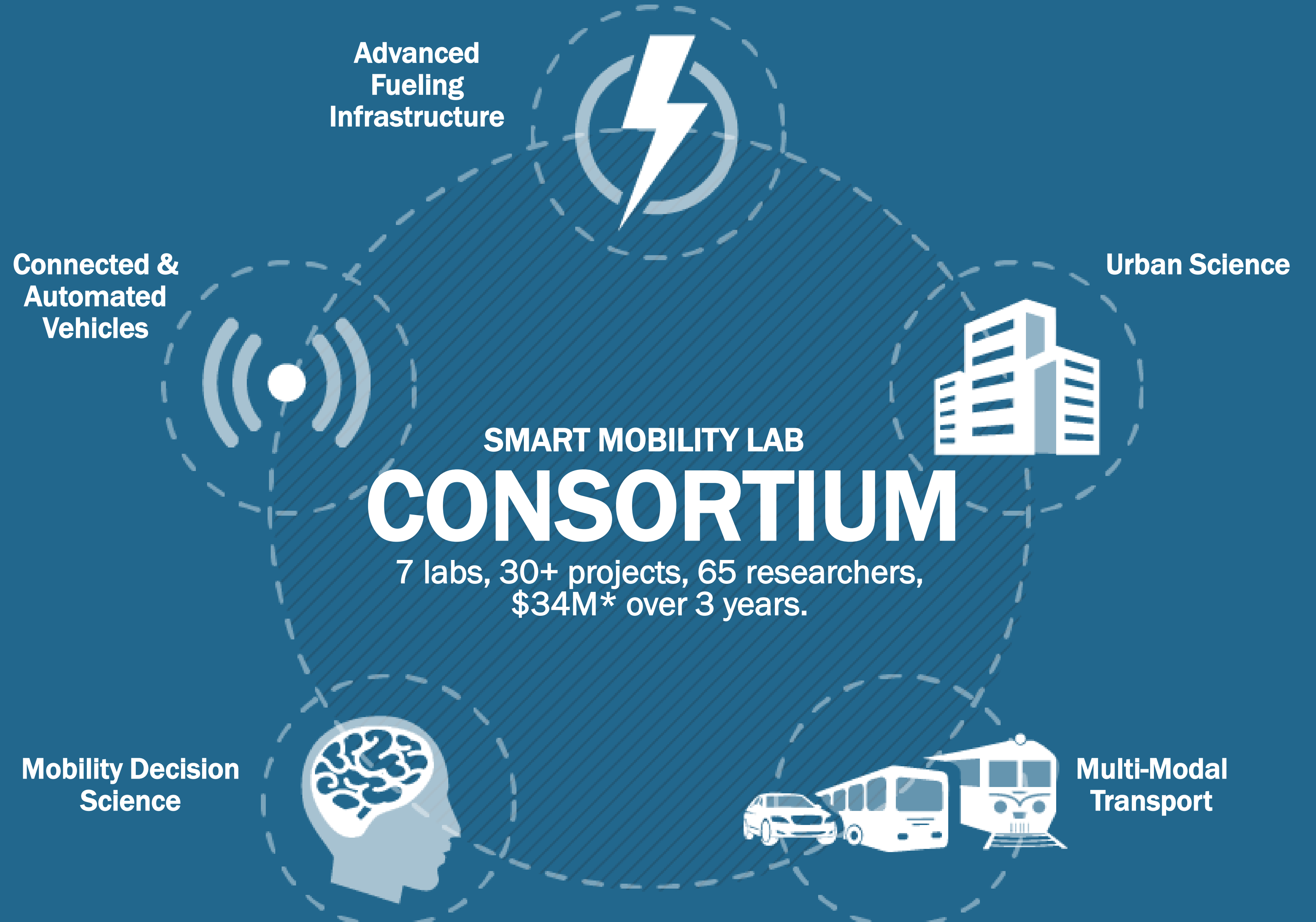
ENERGY EFFICIENT MOBILITY SYSTEMS PROGRAM INVESTIGATES

MOBILITY ENERGY PRODUCTIVITY

THROUGH FIVE EEMS ACTIVITY AREAS

- Advanced R&D Projects
- Living Labs
- Smart Mobility Lab Consortium
- Core Evaluation & Simulation Tools
- HPC4Mobility & Big Transportation Data Analytics



*Based on anticipated funding

Overview

Timeline

- October 1, 2017
- September 30, 2018
- 50% complete as of March 31, 2018

Budget

- Total project funding
  - 140K from DOE
    - 110K to LANL
    - 30K to INL
- 0K for FY 2017
- Received $140K for 2018

Barriers

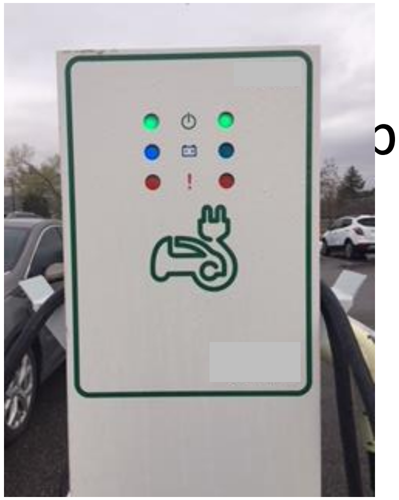
- Understanding how systems will respond to abnormal conditions
- Quantifying Resilience
- Developing systems that will be robust and able to recover from extreme conditions

Partners

- Project Lead: Los Alamos National Laboratory
- Partner: Idaho National Laboratory
- Exploring Collaboration with National Renewable Energy Laboratory
- Interactions with Kansas City

Overview

- Overall Objective: Develop a statistical approach to understanding system resilience strategies for smart city technologies (EVs, CAVs, AMDs,) to assist with planning and mitigation actions during extreme conditions (special events, natural disasters, emergency situations, etc.).



- Objectives for October 2017 – April 2018: o preliminary resilience framework:
  - Develop conceptual model
  - Identify statistical concepts and methods
  - Begin exploring methods using simulated data
- Impact: Provide quantitative approaches for addressing resilience
  - Build quantitative framework
  - Anticipate how systems will respond under stress and plan accordingly

Relevance

- Response to Abnormal Conditions
  - Characterize mobility systems and related infrastructure that impact energy usage under current baseline scenarios and normal conditions
  - Develop an understanding of how systems will respond to stressed and extreme conditions in the presence of new technologies and other disruptions
- Quantifying Resilience
  - Propose metrics that quantify different aspects of system resilience
  - Incorporate data from multiple sources to evaluate resilience metrics
- Development of Robust Systems
  - Assess system behavior across a range of observed conditions
  - Evaluate scenarios outside the range of observed conditions by considering distributions of extremes and incorporating auxiliary information
  - Develop a strategy for monitoring and improving efficiency and the ability to recover from extreme conditions

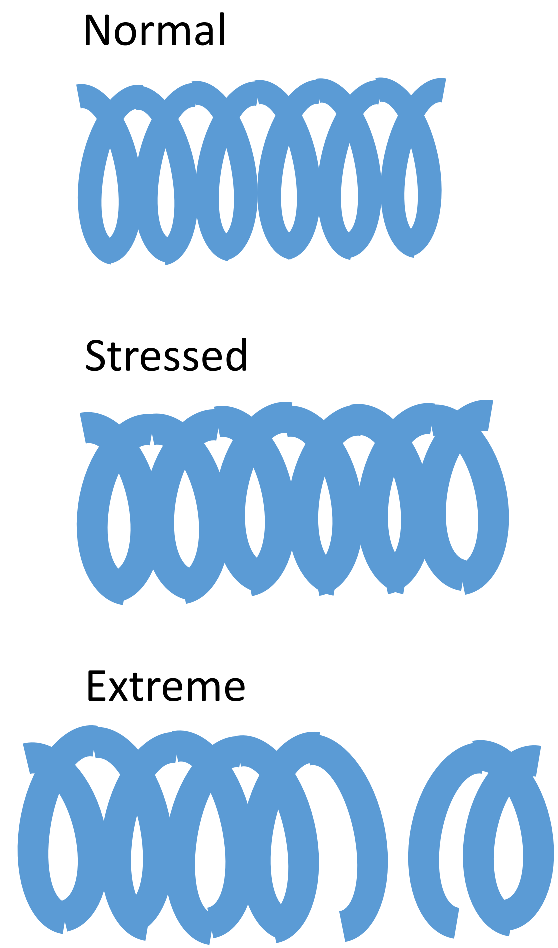
Milestones

- FY18 Q1: Develop preliminary statistical framework for resilience. Identify potential data sources.
- FY18 Q2: March 2018: Implement and test methodology using simulated data.
- FY18 Q3: Execute case study.
- FY18 Q4: Expand framework to more complex settings.

- FY19: Pending funding approval, continue development of resiliency framework and demonstrate usage for specific systems.

Approach: Statistical Planning for Resilience in Next Generation Systems (SPRINGS)

- **Use statistical methods to characterize distributional behavior of systems under normal, stressed, and extreme conditions.**
- Model impact of disruptions to normal operating conditions and resilience of system response as abnormal conditions subside.
- Introduce and study interventions to characterize impact of abnormal conditions on system behavior and key drivers.
- Demonstrate use of resiliency modeling to proactively anticipate and address overcapacity and/or loss of infrastructure for EV/AMD systems.



Technical Accomplishments and Progress

- A Conceptual Model was developed to examine the processes of disruption and recovery.
- A simple closed loop Trolley Simulation was developed which will be extended to more complex system representations.
- Simulation results were used to provide information on the Impact of Changes to System Variables.

- Resilience Metrics and their associated uncertainties were proposed as vehicles for monitoring resilience.
- The SPRINGS approach was proposed for Modeling Extreme Behavior.
- Socio-technological analysis identified key concepts and Resiliency Planning Strategies along with strengths and weaknesses.

Results have been documented via a technical report, a conference poster, and 2 presentations to meet FY18 Q1 and FY18 Q2 deliverables.

Responses to Previous Year Reviewers' Comments

- This project is a new task initiated in FY18.
- This project has not been previously reviewed.

Collaboration and Coordination with Other Institutions

- This Project led by Los Alamos National Laboratory incorporates input and subject matter expertise from Idaho National Laboratory.
- We regularly engage with members of the Urban Science Pillar to exchange ideas and discuss opportunities for partnering. One potential opportunity that has been identified would be to work with NREL on data from Transportation Network Companies.
- We are exploring possible collaboration with NREL on design and analysis of computer experiments for investigating resilience.
- We have been in contact with Smart City Finalist Kansas City planners to explore potential data sources associated with the Kansas City Streetcar and Charging Infrastructure.
- We have also had discussions with individuals from:
  - University of Michigan regarding modeling of campus bus data
  - National Science Foundation regarding their Resilience effort

Remaining Challenges and Barriers

- Modeling extreme behavior is a challenging technical problem, because we are trying to model behavior that may have been observed either infrequently or not at all.
- Validation of our resilience approach will require access to data, which may require significant effort to acquire.
- Data collected for other purposes may not be adequate for modeling resilience.

Proposed Future Research to Develop a Resilience Approach Informed by Data/Models

- Build on preliminary framework to develop and implement the SPRINGS resilience approach.
- Continue efforts to obtain access to mobility system data, such as the Kansas City Trolley, to facilitate development of useful models and results.
- Examine work by other researchers on transit systems, autonomous vehicles, emergencies and disasters and resilience to gain further insights for extending basic framework to more complex situations.
- Actively probe systems and examine flows as different interventions are introduced to experiment with different strategies and observe the impacts on different variables and metrics associated with resilience.
- Develop resilience strategies to allow systems to respond to changing conditions and return to normal operation as quickly as possible following a disruption.
- Explore dynamic visualization methods to enhance the resiliency modeling process and communication of models and results.

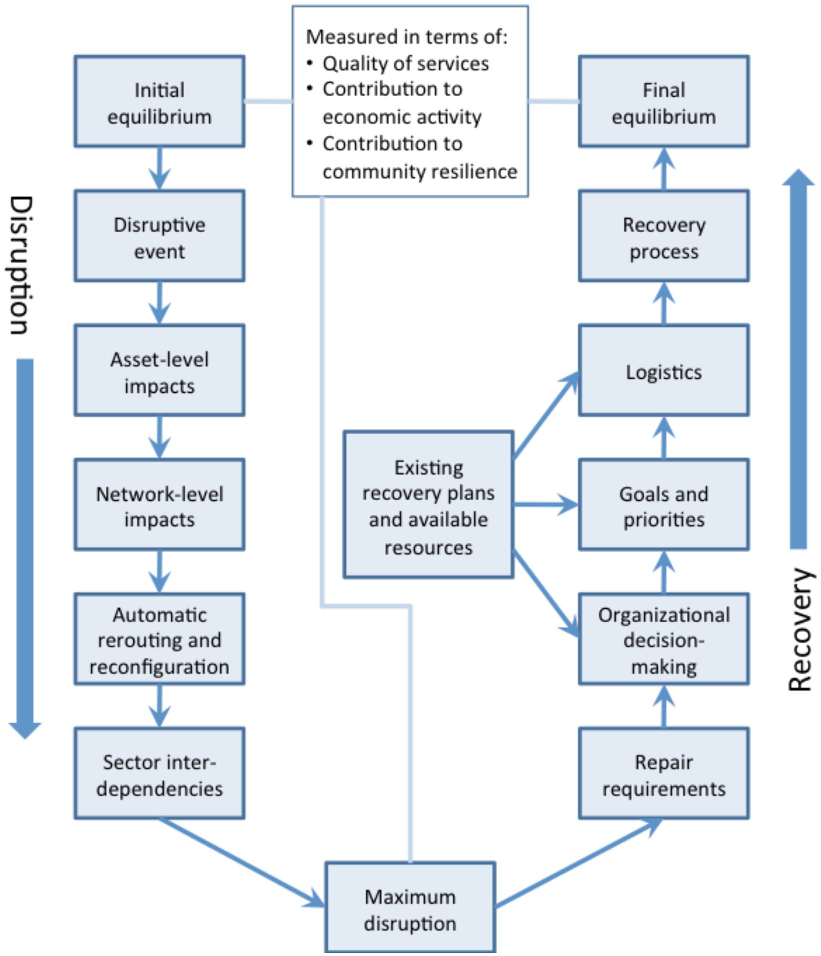
Summary Slide

- We have developed a preliminary resilience modeling framework to support our goal of quantifying and improving resilience in automated mobility systems.
- Our approach is built on socio-technological and statistical modeling and analysis.
- This approach is intended to be broadly applicable. Examples of potential applications include transit systems, on-demand ride-service and charging station infrastructure.

TECHNICAL BACK-UP SLIDES

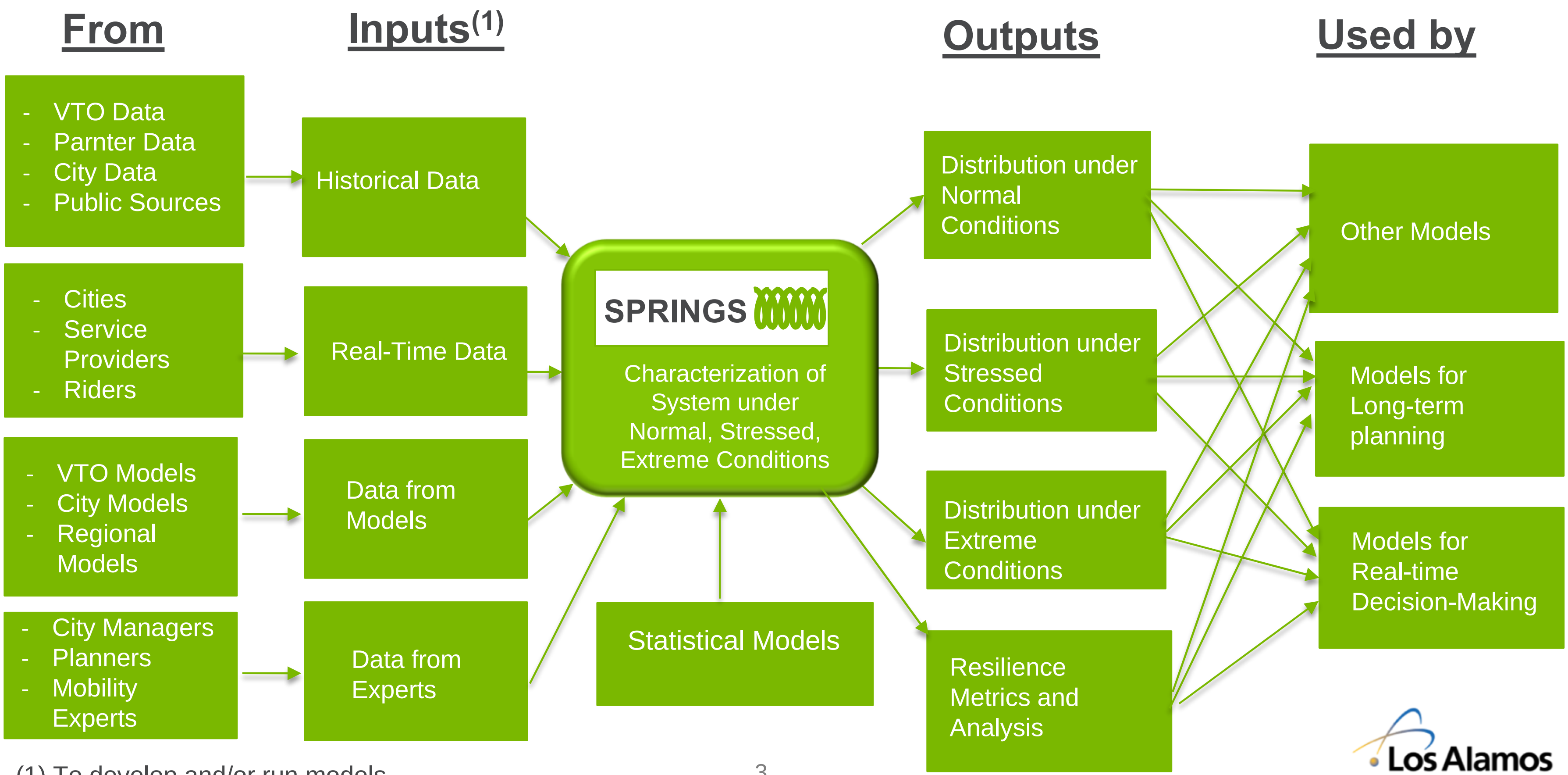
Conceptual Model for Resiliency

We define resilience as:
the resistant characteristics and adaptive capacities of a system that enable it to respond to disruption with lower probability of failure, shorter time to recovery, and/or reduced level of negative impacts (Sims and Brelsford 2011).



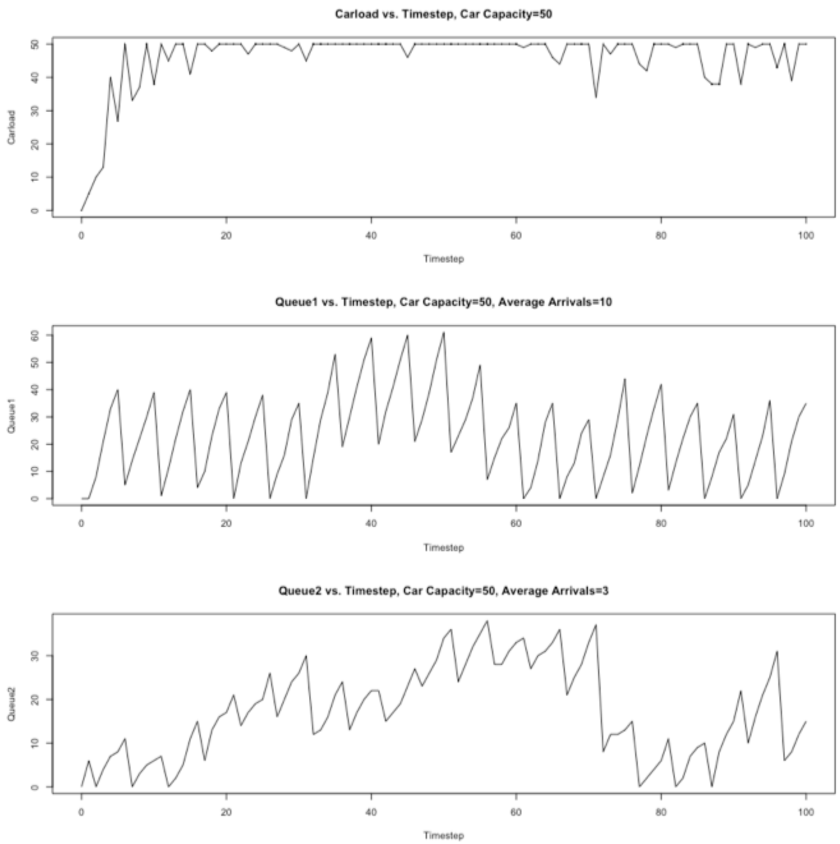
SPRINGS Model

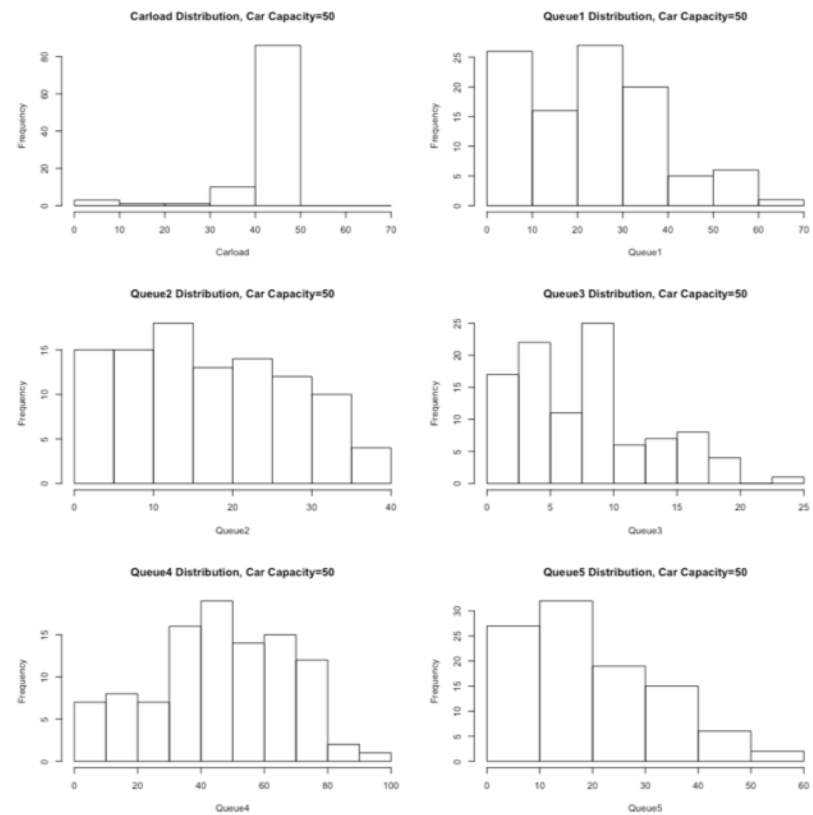
Inputs / Outputs Overview



(1) To develop and/or run models

Use Trolley Simulation to Investigate Passenger Load and Queue Lengths





Quantifying Resilience

- Use Metrics and Distributions to quantify different aspects of resilience.
- Incorporate summary statistics (e.g., mean, median, standard deviation, min, max) to examine location and dispersion of system variables.
- For the trolley example, variables of interest include:
  - the total number of passengers on board the trolley
  - number of passengers waiting at individual stations
  - total number of passengers waiting
  - average wait time across the system
- Calculate combined quantities important to resilience assessment.
  - Average Wait Time/Target Wait Time,
  - Average Queue Length/Car Capacity
- Consider sources of uncertainty throughout the modeling process and how they can propagate and impact decision-making.
- Derive statistical estimates and intervals that rigorously reflect uncertainties in the system including lack of data and knowledge about extremes.

Resilience Planning

Strategies to increase resiliency that might be applied to transportation systems include:

- *Adding redundancy,* for example by building networks that afford multiple access paths to each node.
- *Maintaining excess capacity*, for example by keeping a reserve stock of vehicles on hand to respond to unusual circumstances
- *Adding flexibility*, for example by incorporating on-demand transportation solutions that enable system reconfiguration on the fly without disruption to passenger access (see Cox et al. 2011 and Madni and Jackson 2009 for additional examples).

These strategies each have strengths and weaknesses in relation to different modes of transportation system disruption, including:

- ***Point failures***, such as removal of isolated tracks, road segments, or stations from service
- ***Global capacity degradation***, for example from a snow storm that reduces vehicle speed across an entire transportation system
- ***Demand surges***, for example from large numbers of people trying to get to or evacuate from a particular area
- ***Logistical failures***, such as breakdowns in control systems that optimize vehicle flow through a transportation system